Using the Common Cartridge profile to enhance learning content interoperability

Ricardo Queirós and José Paulo leal
CRACS & DI-ESEIG/IPP, Porto, Portugal
CRACS & INESC-Porto LA, Faculty of Sciences, University of Porto, Portugal
ricardo.queiros@eu.ipp.pt
zp@dcc.fc.up.pt

Abstract: The concept of Learning Object (LO) is crucial for the standardization on eLearning. The latest LO standard from IMS Global Learning Consortium is the IMS Common Cartridge (IMS CC) that organizes and distributes digital learning content. By analyzing this new specification we considered two interoperability levels: content and communication. A common content format is the backbone of interoperability and is the basis for content exchange among eLearning systems. Communication is more than just exchanging content; it includes also accessing to specialized systems and services and reporting on content usage. This is particularly important when LOs are used for evaluation.

In this paper we analyze the Common Cartridge profile based on the two interoperability levels we proposed. We detail its data model that comprises a set of derived schemata referenced on the CC schema and we explore the use of the IMS Learning Tools Interoperability (LTI) to allow remote tools and content to be integrated into a Learning Management System (LMS).

In order to test the applicability of IMS CC for automatic evaluation we define a representation of programming exercises using this standard. This representation is intended to be the cornerstone of a network of eLearning systems where students can solve computer programming exercises and obtain feedback automatically. The CC learning object is automatically generated based on a XML dialect called PExIL that aims to consolidate all the data need to describe resources within the programming exercise life-cycle. Finally, we test the generated cartridge on the IMS CC online validator to verify its conformance with the IMS CC specification.

Keywords: eLearning, standards, interoperability.

1. Introduction

Computers and the Internet have broadened the learning experience from the four walls of the classroom to the remote delivery of instructions and educational content by digital means known as eLearning. The evolution of eLearning in the last decades has been astonishing through the inclusion of new paradigms and new platforms exploring and producing a great variety of solutions for the enrichment of the educational experiences. In spite of their number, these platforms live at the expense of the business model adopted and the standardization level supported. Standards can be viewed as "documented agreements containing technical specifications or other precise criteria to be used consistently as guidelines to ensure that materials and services are fit for their purpose" (Bryden, 2003). In the eLearning context, standards are generally developed for the purposes of ensuring interoperability and reusability in systems and in the content and meta-data they manage. Many standards were created by educational organizations to enhance interoperability, reusability, and customization of digital learning content, assessments, collaborative discussion forums, and a diverse set of learning applications.

In this paper we focus on the IMS Common Cartridge. The Common Cartridge provides a standard way to represent digital course materials for use in online learning systems so that such content can be developed in one format and used across a wide variety of learning systems. We analyze the Common Cartridge profile based on its interoperability levels: content and communication. In the former, we detail its data model composed by a set of schemata referenced on the CC schema. In the latter, we explore the use of the IMS LTI specification to enable web service invocation and data exchange among distributing learning applications.

The study was the starting point to evaluate the applicability of IMS CC to describe programming exercises in a network of eLearning systems where students can solve computer programming exercises and obtain feedback automatically. Networks of this kind include systems such as learning management systems (LMS), evaluation engines (EE), learning objects repositories (LOR) and exercise resolution environments (ERE). Our strategy to achieve the interoperability among these tools is based on a shared definition of a programming exercise as a Learning Object. This shared definition is formalized using the IMS CC specification. The CC learning object is automatically generated based on a XML dialect called PExIL. This XML dialect aims to consolidate all the data

need to describe resources that are useful on the programming exercise life-cycle. To test this CC learning object we introduce the IMS CC conformance framework used to verify the compliance of the cartridges with the IMS CC specification and additional constraints (e.g. static, dynamic and conditional constraints).
The remainder of this paper is organized as follows. Section 2 traces the evolution of standards on the eLearning realm. In the following section we detail the IMS CC information profile highlighting the Common Cartridge structure and the Learning Tools Interoperability specification. Then, we test the applicability of the IMS CC interoperability levels based on the definition of a new CC learning object for representing programming exercises and we test the cartridge structure using the IMS validator. Finally, we conclude with a summary of the main contributions of this work and a perspective of future research.

2. eLearning standards

In the last decade practitioners of eLearning started valuing more the interchange of course content and learners' information, which led to the definition of new standards. These standards are generally developed to ensure interoperability and reusability in content and communication. In this context, several organizations (IMS, IEEE, ADL, ISO/IEC) have developed specifications and standards (Friesen, 2005). These specifications define, among many others, standards related to learning objects (Rehak and Mason, 2003), such as packaging them, describing their content, organizing them in modules and courses and communicating with other eLearning systems.
Packaging is crucial to store eLearning material and reuse it in different systems. The most widely used content packaging format is the IMS Content Packaging (IMS CP, 2007). An IMS CP learning object assembles resources and meta-data into a distribution medium, typically an archive in zip format, with its content described in a manifest file in the root level. The manifest file - named imsmanifest.xml - adheres to the IMS CP schema and contains several sections such as *Metadata* to describe the package as a whole and *Resources* to refer to resources (files) needed for the manifest and metadata describing these resources.
The metadata included in the manifest uses another standard - the IEEE Learning Object Metadata (LOM, 2002). The IEEE LOM is a data model used to describe a learning object. The model is organized in several categories that cover general data, such as title and description, technical data such as object sizes, types and durations, educational characteristics and intellectual property rights, among many others. These categories are very comprehensive and cover many facets of a LO. However, LOM was designed for general LO and does not to meet the requirements of specialized domains, such as the automatic evaluation of programming exercises. For instance, there is no way to assert the role of specific resources, such as test cases or solutions. Fortunately, IMS CP was designed to be straightforward to extend through the creation of application profiles.
The term Application Profile generally refers to "the adaptation, constraint, and/or augmentation of a metadata scheme to suit the needs of a particular community". A well know eLearning application profile is SCORM (SCORM, 2004) that extends IMS CP with more sophisticated sequencing and Contents-to-LMS communication.
The IMS GLC is also responsible for another application profile, the Question & Test Interoperability (QTI, 2006) specification. QTI describes a data model for questions and test data and, since version 2.0, extends the LOM with its own meta-data vocabulary. QTI was designed for questions with a set of pre-defined answers, such as multiple choice, multiple response, fill-in-the-blanks and short text questions. Although long text answers could be used to write the program's source code, there is no way to specify how it should be compiled and executed, which test data should be used and how it should be graded. For these reasons we consider that QTI is not adequate for automatic evaluation of programming exercises, although it may be supported for sake of compatibility with some LMS.
Recently, IMS Global Learning Consortium proposed the IMS Common Cartridge (IMS CC, 2011) that adds support for several standards (e.g. IEEE LOM, IMS CP, IMS QTI, IMS Authorization Web Service) and its main goal is to shape the future regarding the organization and distribution of digital learning content.
The standardization of the learning content it is not enough to ensure interoperability, which is a major user concern with the existing systems (Leal and Queirós, 2010). In the last few years there have been initiatives (Holden, 2004) to adapt Service Oriented Architectures (SOA) to eLearning. These initiatives, commonly named eLearning frameworks, had the same goal: to provide flexible learning environments for learners worldwide. While eLearning frameworks are general approaches for eLearning system integration, several organizations proposed service oriented approaches specifically targeted to the LMS (IMS Digital Repository Interoperability – IMS DRI) and Repositories (IMS LTI).

The IMS DRI specification provides a functional architecture and a reference model for repository interoperability composed by a set of recommendations for common repository functions, namely the submission, search and download of LOs. It recommends the use of web services to expose the repository functions based on the Simple Object Access Protocol (SOAP) protocol, defined by W3C. Despite the SOAP recommendation, other web service interfaces could be used, such as, Representational State Transfer (REST) (Fielding, 2005).
A common interoperability standard that is increasingly supported by major LMS vendors is the IMS Learning Tools Interoperability (IMS LTI) specification. It provides a uniform standards-based extension point in LMS allowing remote tools and content to be integrated into LMSs. The main goal of the LTI is to standardize the process for building links between learning tools and the LMS. The IMS launched also a subset of the full LTI v1.0 specification called IMS Basic LTI. This subset exposes a unidirectional link between the LMS and the application. For instance, there is no provision for accessing run-time services in the LMS and only one security policy is supported (IMS BLTI, 2010).

3. The IMS Common Cartridge Profile

The IMS Common Cartridge specification defines an open format for the distribution of rich web-based content. Its main goal is to organize and distribute digital learning content and to ensure the interchange of content across any Common Cartridge conformant tools. The latest revised version (1.1) was released in May 2011. The IMS CC package organizes and describes a learning object based on two levels of interoperability: content and communication as depicted Figure 1.

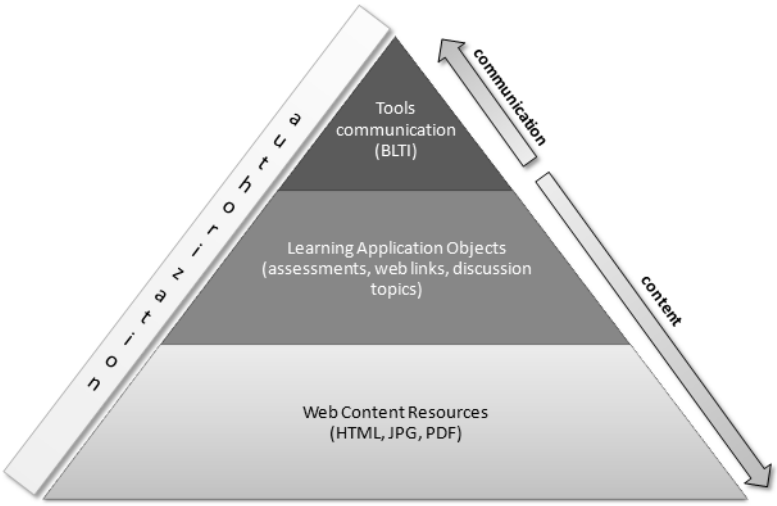

Figure 1: Common Cartridge Content Hierarchy.

In the **content level**, the IMS CC includes two types of resources:

- Web Content Resources (WCR): static web resources that are supported on the Web such as HTML files, GIF/JPEG images, PDF documents, etc.
- Learning Application Objects (LAO): special resource types that require additional processing before they can be imported and represented within the target system. Physically, a LAO consists of a directory in the content package containing a descriptor file and optionally additional files used exclusively by that LAO. Examples of Learning Application Objects include QTI assessments, Discussion Forums, Web links, etc.

In the **communication level** the cartridge describes how the target tool of the cartridge (usually a LMS) should communicate with other remote web applications using the IMS Basic LTI specification. Both levels enhance the interoperability of the cartridge among a network of eLearning systems. In this scope a new IMS CC specification feature is introduced to support authorization at two levels:

either the whole cartridge can be protected or individual resources can be protected. In the following subsections we detail the most important elements of the CC content hierarchy.

3.1 Content Packaging

The Common Cartridge builds upon a profile of the IMS Content Packaging (CP v1.2 schema). The following figure provides a view of the CC manifest.

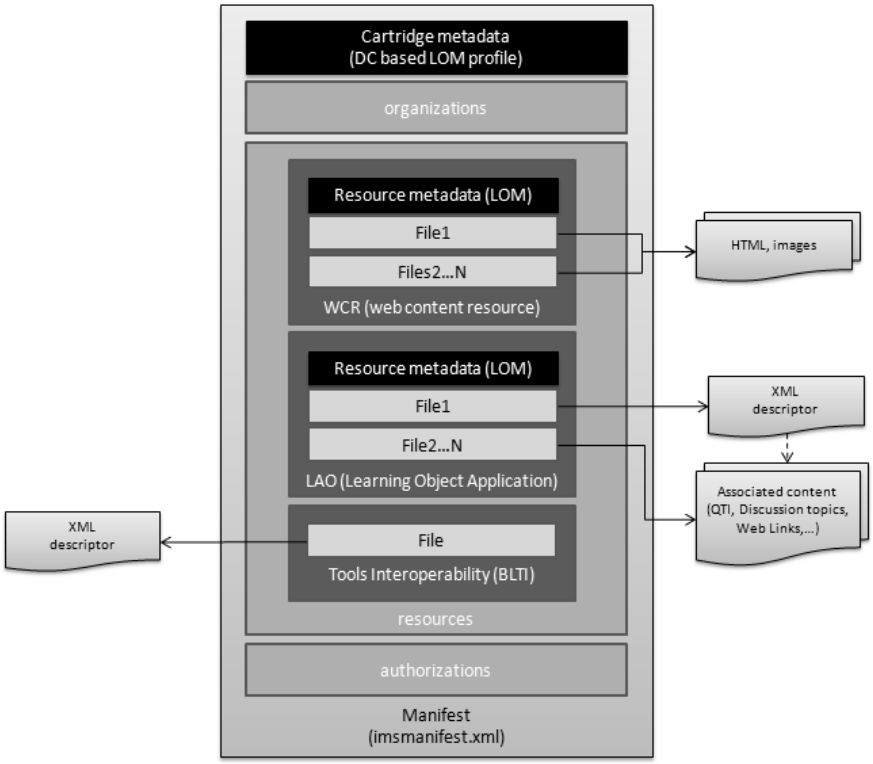

Figure 2: Common Cartridge package.

The manifest is composed by four sections: metadata, organizations, resources and authorizations. The Metadata section is used to store the cartridge metadata restricted to a loose binding of LOM elements based on the Dublin Core (DC) specification. The Organization section will be used to represent the Common Cartridge Folder content type as a structural approach to organize content. The Resources section will be used to refer assets included in the cartridge.

3.2 Metadata

The manifest includes the LOM standard to describe the cartridge and the learning resources included in the cartridge package.The metadata could be include at two levels: cartridge and resources. At the cartridge level we must use metadata according to the Common Cartridge profile of the IEEE LOM (loose binding) which describes the range of a mapping from the core elements of the Dublin Core specification v1.1 to IEEE LOM. At the resources level we could use the original IEEE LOM namespace.

There will be scenarios where resources may need to be specified within the organization, but should not be made visible in player mode upon default import of the cartridge. One such situation is the inclusion of a solution program within the cartridge. To meet these needs, the common cartridge supports the optional “roles” meta-data associated with the resource in the manifest file. The supported roles in the IMS CC version 1.1 are: Learner, Instructor and Mentor. If case of absence of the role the resource would be viewable by all users.

3.3 Authorization

An IMS CC learning object supports authorization at three levels: on cartridge import, on cartridge usage and on usage of specific resources in the cartridge. The mechanism by which the authorized access to particular resources is enforced by the tool is not defined by the profile. The following code shows the use of the authorization element that extends the manifest to protect the learning object as a whole.

```
<manifest>
   <metadata/>
   <organization/>
   <resources/>
   <cc:authorizations access="cartridge" import="false" xmlns:…>
      <cc:authorization>
        <cartridgeId>12345</cartridgeId>
        <webservice>http://publisher.com/authme</webservice>
     </cc:authorization>
   </cc:authorizations>
</manifest>
```

Note that the address of the web service must support the Authorization Web Service as described in IMS Common Cartridge Authorization Web Service. If the access attribute of the authorizations element is set to `resource` then the individual resources which need to be protected are specified by adding the `protected` attribute to each resource.

```
<resource identifier=res001 type=webcontent" cc:protected="true" href=someFile.html>
   <file href=someFile.html/>
</resource>
```

3.4 Questions and Tests

The Common Cartridge uses the IMS QTI specification as a data model for questions and tests. This specification is represented on the manifest through two LAO resource types: assessments and question banks.

An **assessment** represents an ordered question set (e.g. Multiple Choice, True/False, Fill in the Blanks, Pattern Match, and Essay) and may include optional attributes (e.g. number of attempts, time limit and whether late submission is allowed) that apply to the set as a whole.

A **question bank** can embed any of the question types supported by the CC v1.1 profile of QTI. Only one question bank can optionally be included in a cartridge.

3.5 Web links

A Web Link is a LAO resource that extends a standard HTTP link. The extension comprises a title and a URL describing a set of window open features such as the dimensions of the window.

This approach allows the cartridge to minimize its storage space and to have content updates after distribution. Web links are described in a descriptor file as follows:

```
<webLink xmlns=…>
  <title>The C Language</title>
  <url href=" http://en.wikipedia.org/wiki/C_(programming_language)" target="_self"
windowFeatures="width=100, height=100"/>
</webLink>
```

3.6 Discussion Topics

A Discussion Topic is a LAO resource used to initiate a discussion activity. Upon import, the discussion topic content is stored by the tool using its own internal representation. As the cartridge content is added to an actual course, an associated discussion topic is created in the default tool discussion forum. Discussion topics are described in a descriptor file as follows:

```
<topic xmlns… >
  <title>The Psychology of Faces</title>
  <text texttype="text/html">Differences from LMS and CMS? &lt;br/&gt; &lt;img src="$IMS-CC-
FILEBASE$/images/img01.jpg"/&gt;</text>
  <attachments>
    <attachment href="/images/img02.jpg" />
  </attachments>
</topic>
```

The Discussion topic schema supports the use of plain text or HTML for the discussion content and allows the attachment of other resources through the use of the `attachment` element.

3.7 Basic LTI

A Basic LTI resource refers to an XML file that contains the information needed to create a link in a Tool Consumer (e.g. LMS). Upon the user's click, the execution flow passes to a Tool Provider along

with contextual information about the user and Consumer. The Basic LTI link is defined in the resource section of an IMS Common Cartridge as follows:

```
<resource identifier="MyBLTILink" type="imsbasiclti_xmlv1p0">
   <file href="BasicLTI.xml"/>
</resource>
```

The `href` attribute in the resource entry refers to a file path in the cartridge that contains an XML description of the Basic LTI link. A BLTI link contains several elements. The most important are: the `title` and `description` elements contain generic information about the link; the `custom` and `extensions` elements allow the Tool Consumer to extend the basic communication data; the `launch_url` element contains the URL to which the LTI invocation is sent; the `secure_launch_url` element is the URL to use if secure http is required.

4. Applicability to automatic evaluation

In order to test the applicability of these interoperability levels to the automatic evaluation we define a new CC learning object for representing programming exercises. These LOs are exchanged in a network of eLearning systems where students can solve computer programming exercises and obtain feedback automatically. Networks of this kind include systems such as LMS, evaluation engines (EE), learning objects repositories (LOR) and integrated development environments (IDE). This specialized cartridge includes a LTI descriptor referenced in the manifest by LAO resource. The use of this LTI descriptor will allow a secure integration of the cartridge from the place where it is referenced (e.g. LMS) to the place where it will be used (e.g. ERE).

4.1 PExIL

The Question and Tests Interoperability (QTI) is used on IMS CC to describe simple exercises. However, QTI was designed for questions with predefined answers and cannot be used for complex evaluation domains such as the programming exercise evaluation. A programming exercise requires a collection of files (e.g. test cases, solution programs, exercise descriptions, feedback) and special data (e.g. compilation and execution lines). These resources are interdependent and processed in different moments in the life-cycle of the programming exercise. To address these issues we create a XML dialect (Queirós and Leal, 2011) – called **PExIL (Programming Exercises Interoperability Language)** – whose aim is to consolidate all the data required in the programming exercise life-cycle, from when it is created to when it is graded, covering also the resolution, the evaluation and the feedback.

4.2 Generation of an IMS CC package

In order to validate the PExIL usefulness we created a tool (named PexilUtils) to generate several resources related to the programming exercise life-cycle (e.g. exercise descriptions in multiple languages, test cases, feedback files). The LO generation is depicted in Fig. 3.

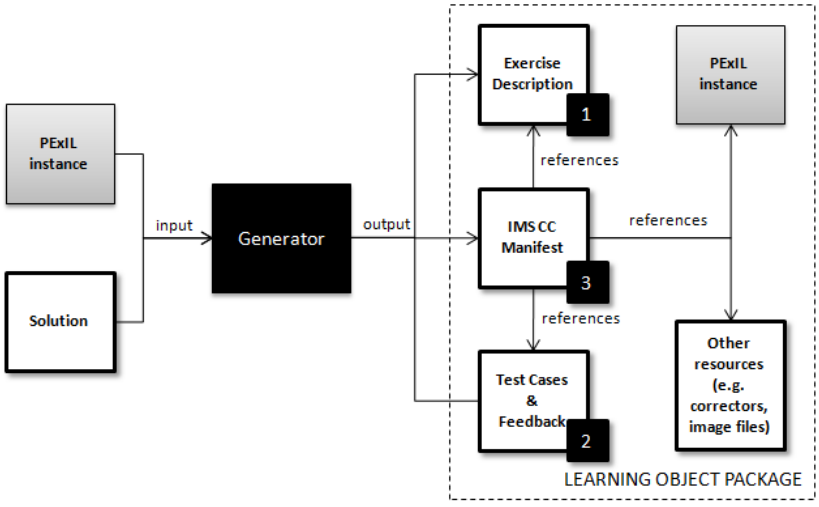

Figure 3: Common Cartridge package generation.

The Generator tool uses as input a valid PExIL instance and a program solution file and generates 1) an exercise description in a given format and language, 2) a set of test cases and feedback files and 3) a valid IMS CC manifest file. Then, a validation step is performed to verify that the generated tests cases meet the specification presented on the PExIL instance and the manifest complies with the IMS CC schema. Finally, all these files are wrapped up in a file (with the .IMSCC extension) and deployed in a Learning Objects Repository.
From the several manifest sections included in the last version of the IMS CC specification only two were addressed in the generation phase: metadata and resources. The former is fed by the generator using a binding of the PExIL textual elements (e.g. title, authors, date) to the corresponding LOM elements. The latter contains a list of references to other files in the archive (resources) and dependency among them. The next figure shows the resources section of the generated CC manifest.

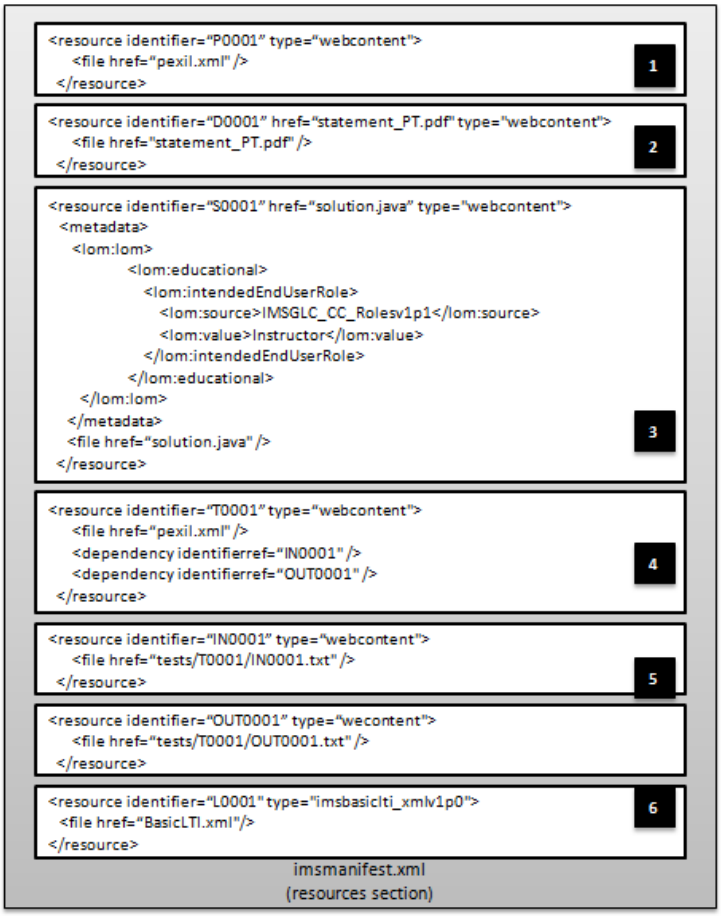

Figure 4: Resources section of the IMS CC LO manifest of a programming exercise.

The resources section starts with a LAO resource (1) pointing to the PEXIL descriptor. This file is responsible for the automatic generation of all the other files included in the package (with the exception of the solution program and images). The description of the exercise is included on the manifest as a WCR resource (2). This type of resources can be automatically rendered by the browser without any additional processing. The program solution (3) is associated with metadata since this resource should not be made visible in player mode to the students and will be used only to regenerate test cases and in the evaluation phase of the programming life-cycle. The test cases are depicted as LAO resources (4) comprising the PEXIL descriptor and a pair of input and output files referenced by dependency elements and defined individually as resource objects (5). Finally, the BLTI link is included as a LAO resource (6). This link points to a XML file that includes all the data needed to integrate the cartridge in a LMS-web application communication.

4.3 Validation

In this subsection we report on our efforts to validate the IMS CC cartridges previously generated using the IMS validator at http://validator.imsglobal.org. This system validates cartridges for conformance with the IMS Common Cartridge v1.0 and/or v1.1 specification. In the validation process the IMS CC Validator test the whole cartridge verifying the following type of constraints:

1) Static: the parameters (e.g. file names) are fixed in the profile (e.g. `imsmanifest.xml` must exist at the root of the package)
2) Dynamic: the parameters are taken from an instance document in the package (e.g. `href` attribute of a `resource` element must point to a QTI file)
3) Conditional: the constraint depends on a condition (e.g. If parameter '`contenttype`' is '`question`' then the `href` attribute must point to a QTI file).

The cartridges generated from PExIL instances using the methodology presented in the previous sub-section passed all tests performed by the validator.

5. Conclusion

In this paper we present a comprehensive study on the new IMS CC specification. For this study we analyzed this specification at two interoperability levels: content and communication. At the content level we studied the specifications of LAO resources, such as QTI assessments, Discussion Forums, and Web links. At the communication we studied the IMS BLTI has a means to use the cartridge in a LMS-web application communication. Both levels support authorization through the use of the IMS Common Cartridge Authorization Web Service.

The applicability of IMS CC was tested in a specialized domain: the automatic evaluation of programming exercises. In this scope we defined a new CC learning object for representing programming exercises. These learning objects are automatically generated from a PExIL instance - a XML dialect to describe data for the programming exercises life-cycle. Finally, the generated cartridge was validated using the IMS CC validator to assure the conformance of the cartridge with the IMS CC v1.1 specification.

Our major conclusion is that the IMS CC has a number of improvements when compared with the base specification, the IMS CP. From the standpoint of our intended use, the automatic evaluation of programming exercises, the most relevant features are the BLTI support and the access control at the resource level. The Basic LTI (BLTI) will be instrumental in binding a programming exercise with an environment where the student can resolve it; it can be used to launch exercise resolution environments (ERE) from the LMS with a specific exercise. The access control at the resource level enables an eLearning system (e.g. a LMS) to present the problem solution to the teacher while hiding it from students.

We are currently finishing the development of the generator engine to produce a LO compliant with the IMS CC specification. This tool could be used as an IDE plug-in or through command line based on a valid PExIL instance. A valid PExIL instance can be integrated in several learning scenarios where programming exercises are used, from curricular to competitive learning. For future work we intend to support the PExIL definition in the crimsonHex repository (Leal and Queirós, 2009) – a repository of programming problems.

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